Using regional simulations and spatial lidar to study regional cloud variability

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Context

This work aims to study the clouds' role on regional climate variability. At first order, European climate is driven by large scale circulations. However, clouds are known to have two major radiative effects impacting the surface's temperature: the greenhouse effect and the mask effect. These effects are strongly dependent on macrophysical and microphysical properties of clouds. It is then necessary to consider the vertical distribution of clouds to better understand their impact on regional climate.

Since June 2006, A-train observations are available and allow the description of this vertical distribution and of other microphysical properties. However, the sampling is limited. To complete these observations, we use a regional climate model which may allow to extend the period of study and to better understand the link between clouds and surface temperature.

In this study we are evaluating our tools and estimating the sampling bias in order to know which scale we can consider with these tools. We are also considering clouds' distribution of the particularly warm winter of 2007.

Tools

GOCCP (GCM Oriented Calipso Cloud Product)

-Active measurements

-Vertical structure of clouds (40 levels)

-Products comparable to GCM data

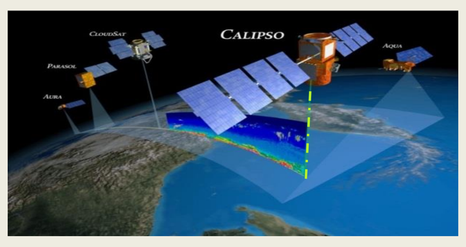

Fig1: CALIPSO's lidar track

- Sun synchronous orbit satellite
- 30-60m vertical resolution
- horizontal day track resolution 330m
- measurements frequency: every 16 days

$$ATB(z) = (\beta_{sca,part}(z) + \beta_{sca,mol}(z)).\ e^{-2\int_{TOA}^{z}(\alpha_{sca,mol}(z)+0.7.\alpha_{sca,part}(z)).dz}$$

2 GOCCP products have been used for this study:

- Scattering Ratio:
- Cloud fraction (z) : % of computed on 20km grid

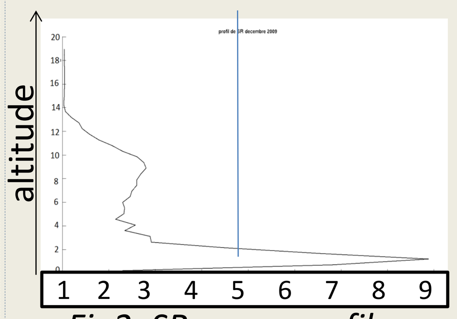

Fig2: SR mean profile 12/2009

SR threshold	detection
0<SR<0.01	Fully attenuated
0.01<SR<1.2	clear
1.2<SR<5	unclassified
5<SR	cloudy

Tab1: SR detection threshold

WRF-MedCordex simulations

We use a WRF simulation performed in the framework of MED-CORDEX (downscaling of ERA-interim reanalyses) that covers the Mediterranean domain, over the period 1989-2011.

- horizontal resolution: 20km

- 28 vertical levels, outputs every 3 hours

(See poster Bastin Tuesday topic 7 for further details)

=> 2 problems:

- Two different samplings due to spatial and temporal resolutions (Fig. 3)
- WRF outputs generate mixing ratios of ice, snow and liquid clouds (WSM5 scheme): Not comparable to the lidar signal (SR)! => lidar simulator

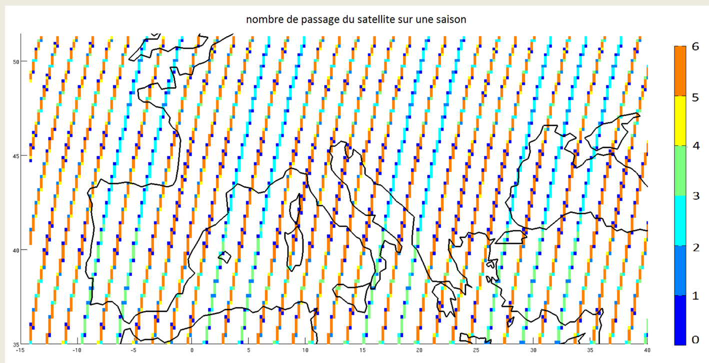

Fig3: CALIPSO seasonal track occurrence

Adaptation of COSP Lidar Simulator

Using the microphysics properties of the simulated clouds, we compute the SR that would be observed by the CALIOP lidar. We can then use the same clouds diagnostics for both observations and simulations

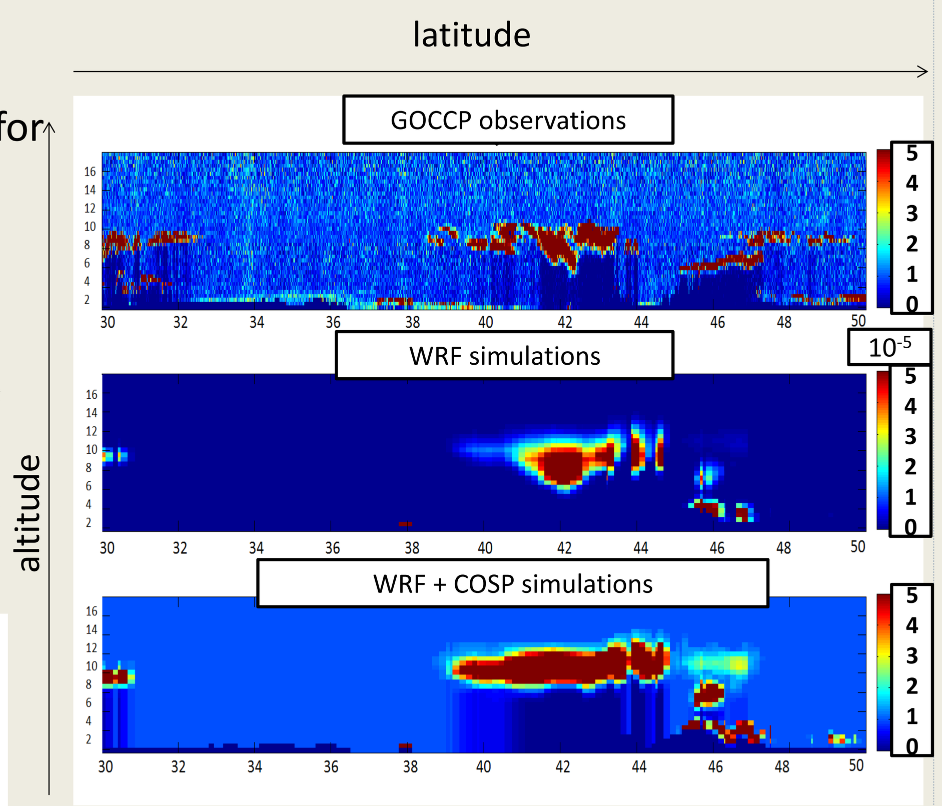

Fig4: Instant SR 2009 01 19 night: Observations, WRF simulations and WRF+lidar simulator simulations

How much can we use CALIPSO observations and/or WRF simulations to study cloud variability over Europe?

A. Calipso Sampling evaluation

Comparison of simulated cloud fraction (bottom) and SR (right) between satellite sampling (WRF profiles corresponding to CALIPSO measurement) and WRF sampling (one profile per day at each grid point)

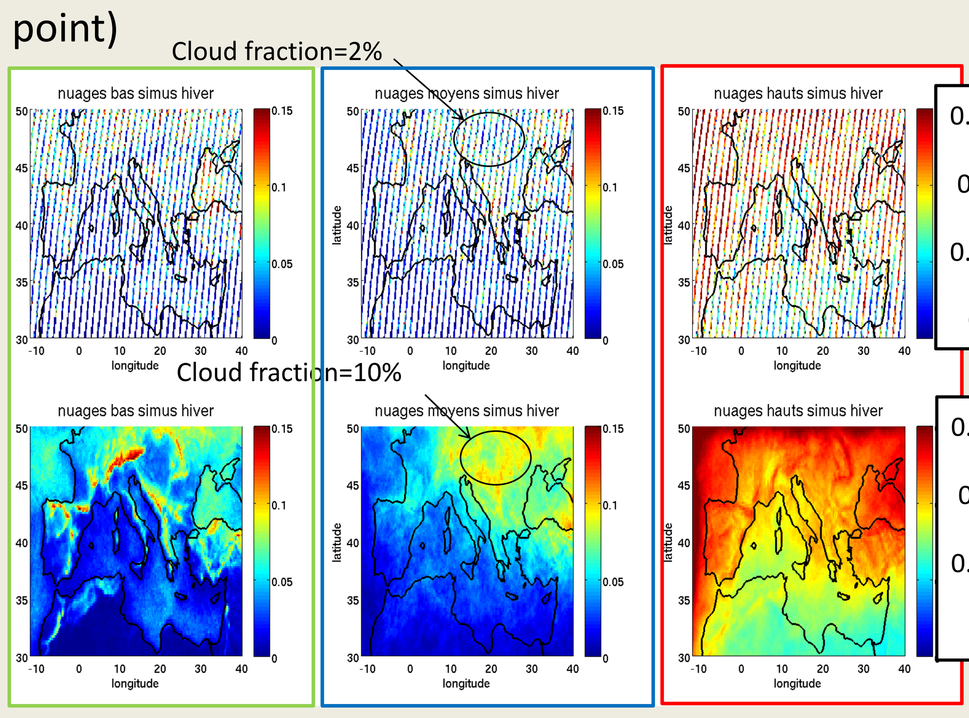

Fig5: low, mid and high simulated clouds with CALIPSO sampling on the top and WRF sampling on the bottom

➡ the majority of cloud structures are found with the two different samplings.

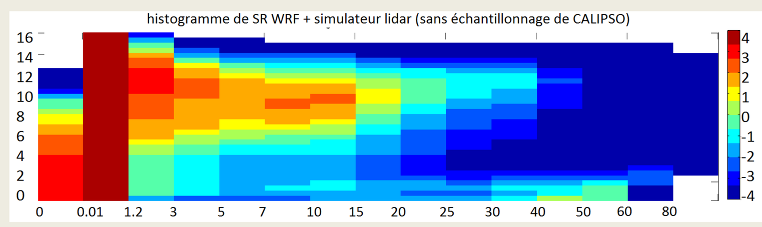

Fig7: SR simulation histograms

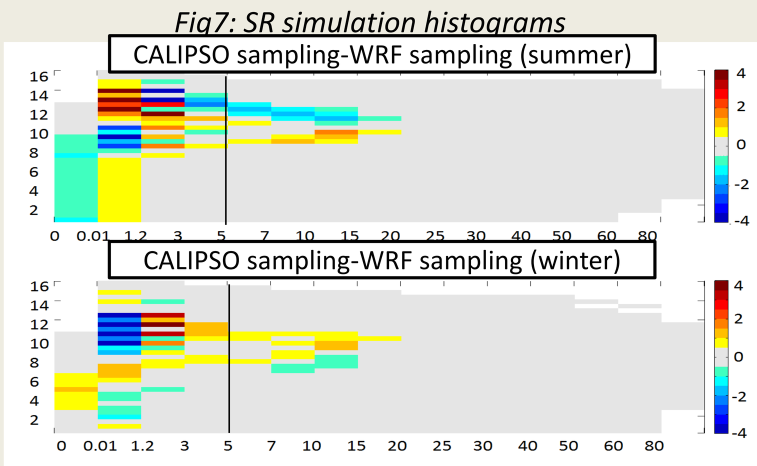

Fig6: Difference between SR simulated histograms CALIPSO sampling – WRF sampling in summer (top) and winter (bottom)

- Light overestimation of high clouds in winter and underestimation in summer (2%) with the CALIPSO sampling
- It induces a slight overestimation of attenuated signals at lower levels in winter and underestimation in summer.

B. Model evaluation

Comparison of SR histograms (left) and vertical cloud distribution (right) between observations and WRF simulations (same sampling).

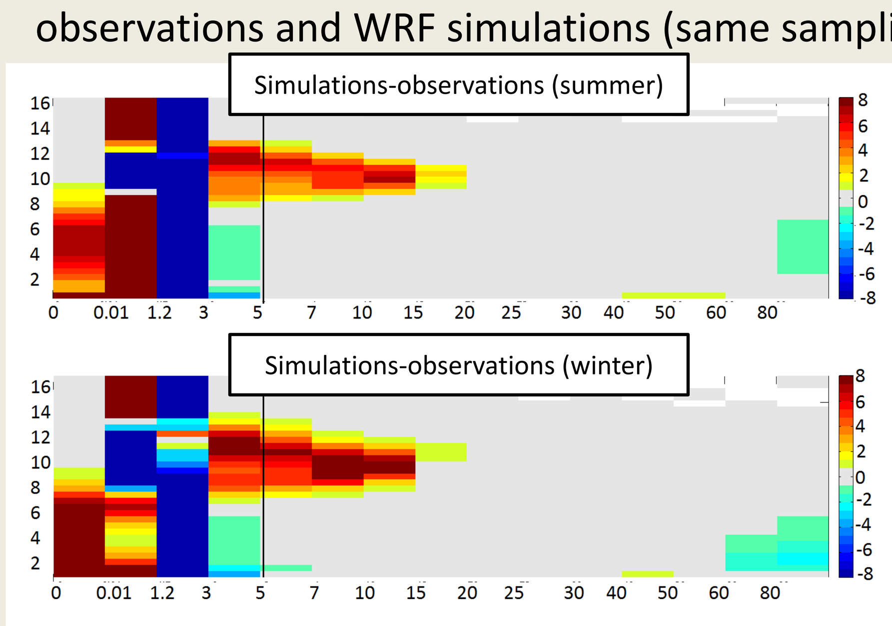

Fig7: Difference between simulated SR and observed SR in Summer (top) and winter(bottom)

- Overestimation of high clouds in the model, especially at lower latitudes => more profiles are attenuated => less low clouds detected by SR threshold
- Underestimation of low clouds, especially in summer, and over ocean in winter => need complementary analyses

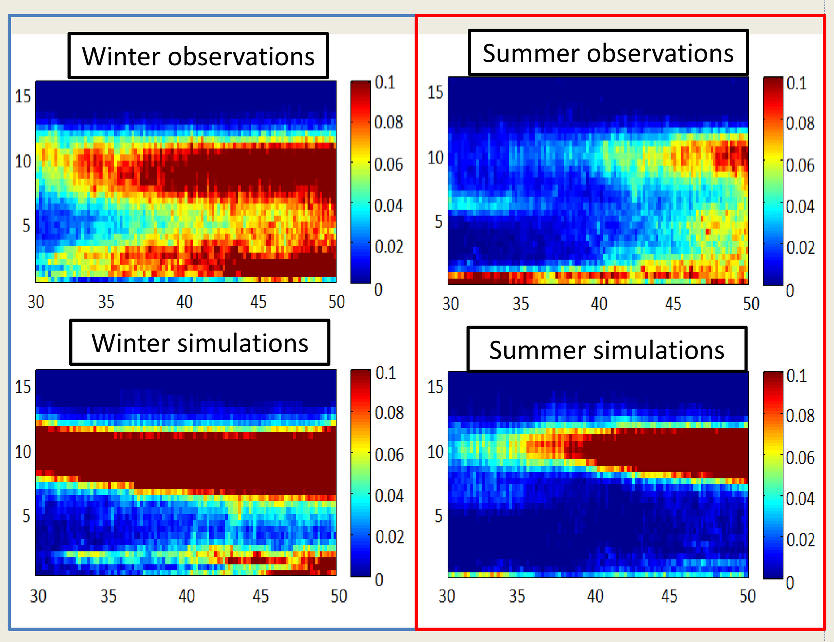

Fig 8: Vertical clouds distribution zonally averaged for observations (top) and simulations (bottom) in summer and winter

Case study: Winter 2007

- At 1st order, the mean seasonal temperature over Europe is largely explained by the frequency of the weather regimes during the concerned season (Palmer,1999).
- But P.Yiou (2007) showed that the exceptional warm fall/winter of 2007 (fig.9) was not driven by changes in mid flow situations.

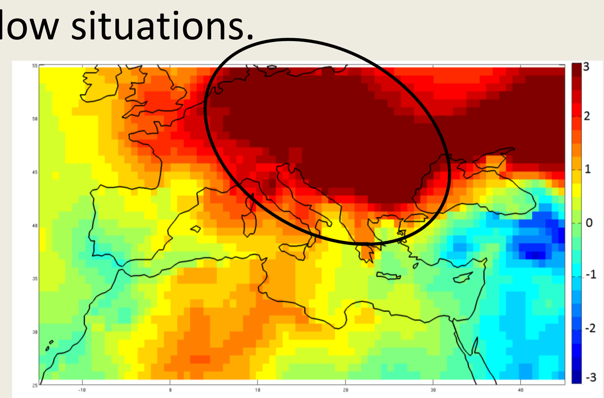

Fig9: Temperature Anomaly °C over Europe during winter 2007 (December2006,January and February2007)

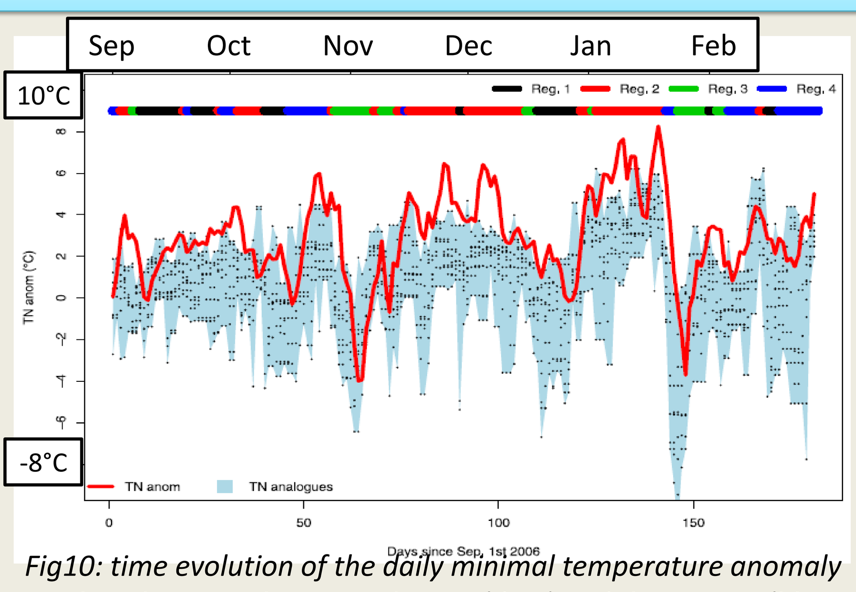

Fig10: time evolution of the daily minimal temperature anomaly with 10 best circulation analogues (dots) and their range (blue shade) (Yiou et al. 2007)

In figure 10, Yiou compared best ten fall/winter analog circulations (blue shade) since 1948 with the observed temperatures (red line) and conclude that even with a similar circulation, T of 2007 is higher => role of clouds?

From observations (Fig. 11), over the 6 available years, spatially averaged cloud fraction without weather regime separation doesn't show a special signal for winter 2007 (the strong signal for year 2010 is due to persistence of NAO- weather regime):

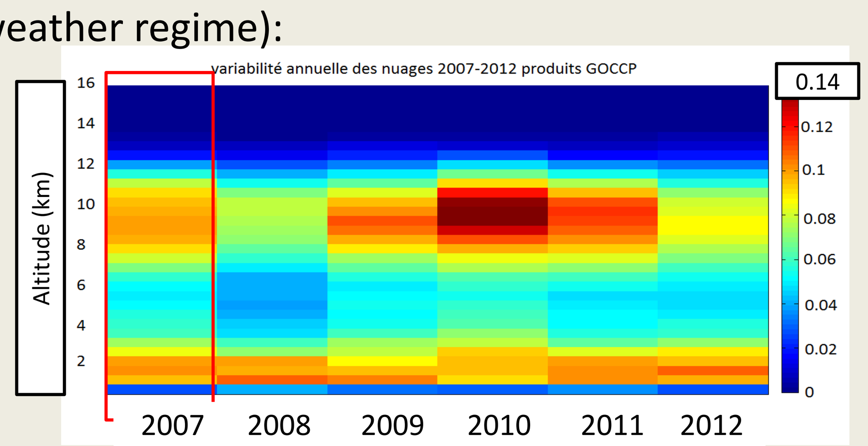

Fig 11: Horizontally averaged winter cloud fraction annual evolution

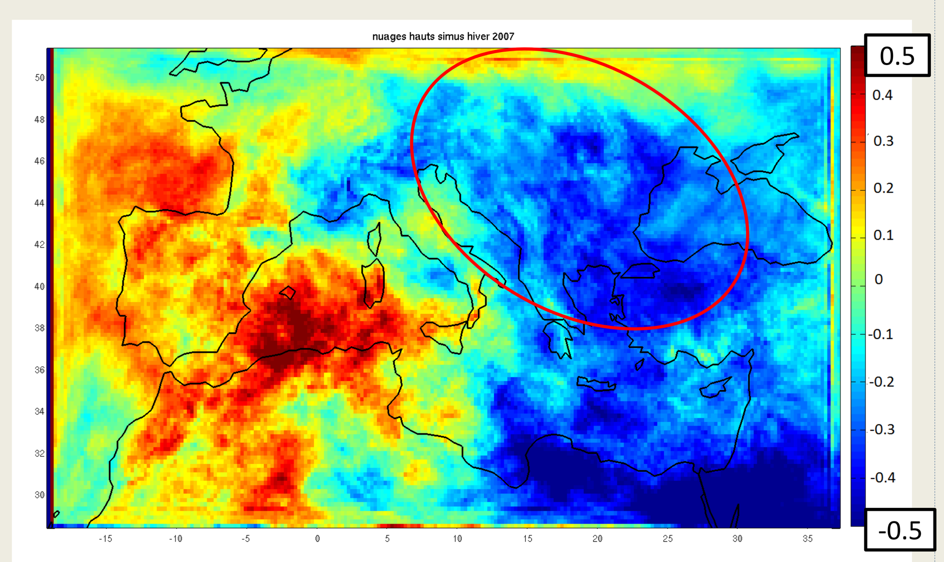

Fig12: High clouds standardized anomaly relative to 1990-2011 mean high clouds

But from simulations, over a longer period, a west-east temperature anomaly structure is found (fig. 12) with 40% less clouds over central Europe (where maximum of temperature anomaly is observed, fig. 9) and 40% more clouds over western Mediterranean sea and Europe.

Conclusion and perspectives

-CALIPSO sampling: insignificant bias over the 7 years but not enough tracks over a season to study interannual variability or anomaly at 20 km resolution (max 6 profiles by grid points)

-Model overestimates high clouds and therefore more profiles are attenuated. It leads to less low clouds detection. Study with ground based lidar shows that this simulation actually underestimates low clouds in summer but not in winter over continent. However, the radiative impact of these differences should be evaluated.

-Particularly warm Winter 2007 associated with significant high clouds anomaly

- Only a preliminary study, deeper investigations and improvements are needed.
- Looking into spring and fall clouds signature to test the method's sensibility and better understand cloud's seasonal variability
- Extracting daytime observation and simulation data to have the daytime clouds signature but also to improve the data sampling
- Characterize clouds radiative forcing with A-train observations

References and acknowledgements

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Acknowledgements:

This work is a contribution to the EECLAT project through LEFE/INSU and TOSCA/CNES supports and *to the HyMeX program through INSU-MISTRALS support, and the Med-CORDEX program. Simulation was performed using GENCI with granted access to the HPC resources of IDRIS (under allocation i2011010227). The authors would like to thank climserv team for computing and storage resources.*